

**FUNDAMENTALS OF
SEMICONDUCTOR PROCESSING
TECHNOLOGY**

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several intervals between polishing and determine the time needed to achieve the required polished thickness.

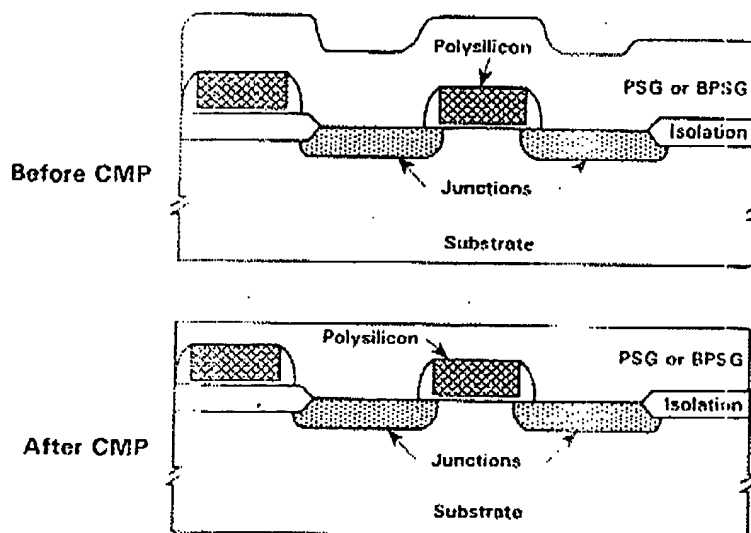


Fig. 8.15 Poly-metal dielectric surface before and after polishing.

8.2.3 Contact Definition

Contacts to silicon or silicide are defined in the insulator using lithography and dry etching techniques discussed in Chaps. 4.5. Dry etching allows the definition of contact openings with high aspect ratio and vertical sidewalls. Since a planar insulator is thinner above polysilicon than above junctions (Fig. 8.15), a sufficiently large etch-rate ratio of insulator to silicon or silicide is required if contacts to both regions are to be etched simultaneously. Alternatively, the substrate surface can be coated with a thin etch-stop, such as silicon nitride, polysilicon, or aluminum oxide, prior to PMD deposition. This allows etching of contact holes to continue to single-crystal silicon without attacking silicide or polysilicon in contacts to the elevated layers. The etch-stop is then removed with an appropriate etchant (Chap. 5). When polysilicon is used as an etch stop, it is important to convert the

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film to silicon dioxide by, e.g., high-pressure oxidation after completing the etch process to avoid high leakage between circuits [63]. After etching, contacts must be cleaned to remove any organic material, residual oxide or debris that can cause adhesion problems or block contacts (Chap. 5).

8.3 Metal Interconnects

Metals used in microelectronics must satisfy several requirements to meet the objectives of circuit performance, yield and reliability. They must exhibit low series and contact resistances, negligible penetration into silicon, good adhesion to insulators and contacted surfaces, excellent uniformity, and resistance to corrosion. The metals must also form bondable films that can be delineated into uniform fine-lines of sub-halfmicron widths and spaces, withstand temperature cycling and operating current densities without failure, and be free of contaminants (such as sodium ions). The most common metals used for interconnections and contact fill are aluminum alloys and tungsten. Aluminum meets most of the above requirements but suffers from a failure mechanism at high current densities known as **electromigration**, discussed in Sec. 8.6. Adding small amounts ($\approx 0.5\%$) of copper to aluminum (or Al-Si) increases the electromigration lifetime. Tungsten is considerably less susceptible to electromigration and can be deposited with greater conformality than physically deposited aluminum. Tungsten, however, exhibits a 2-3 times higher resistivity than aluminum and is typically used in lower-level metals. Copper has also received increased attention because of its higher conductivity and resistance to electromigration than Al. Copper is, however, difficult to delineate and must be "cladded" with a barrier metal to inhibit its diffusion into oxide and silicon where it can cause excessive leakage or shorts [64]. Table 8.4 compares important properties of the three metals.

8.3.1 Metal Deposition

The most widely used techniques to deposit metals are, evaporation, sputtering, and CVD (Chap. 5). Variations to these techniques are collimated sputtering and selective CVD.